An investigation of Mode I and Mode II fracture toughness enhancement using aligned carbon nanotubes forests at the crack interface

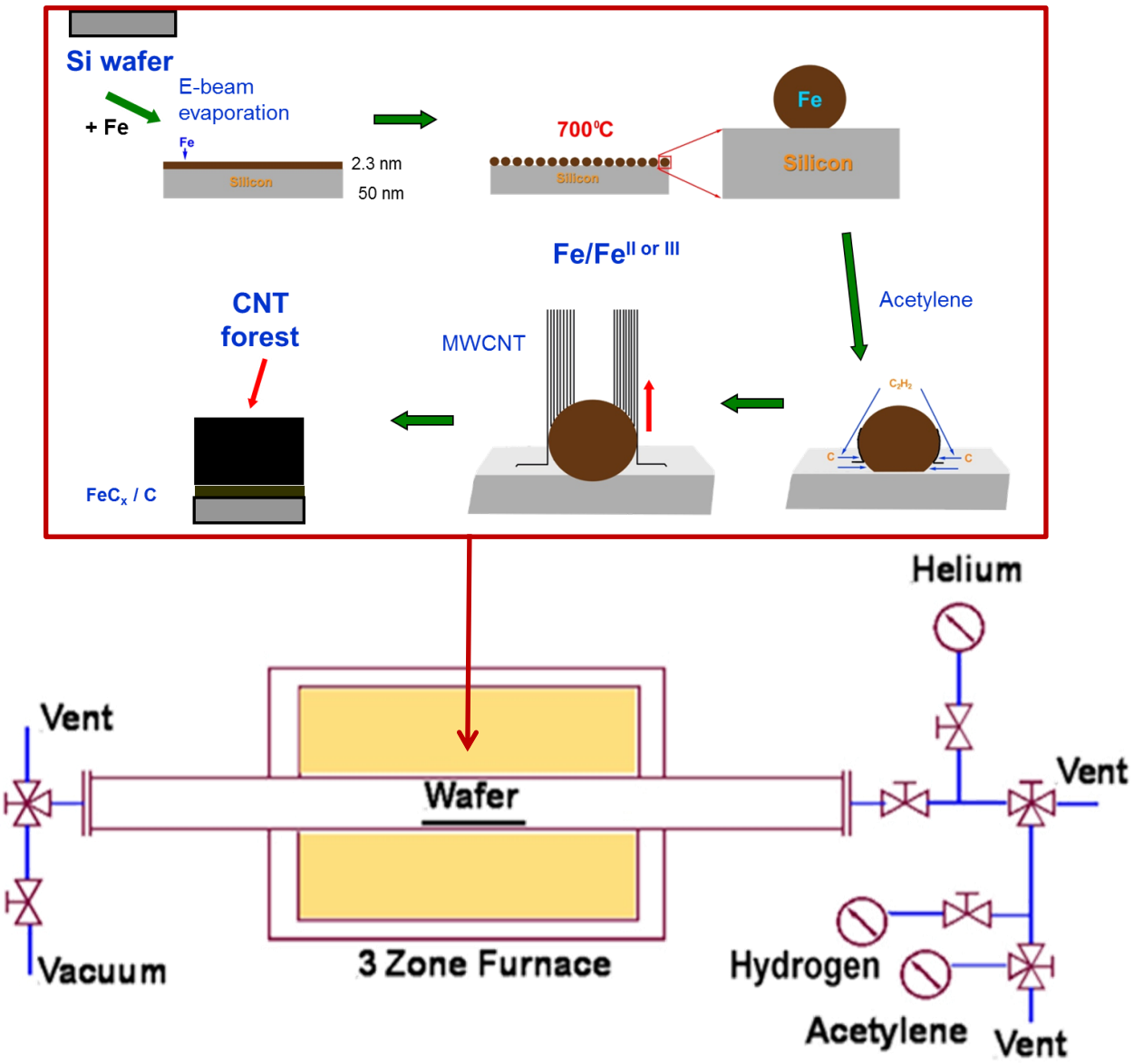
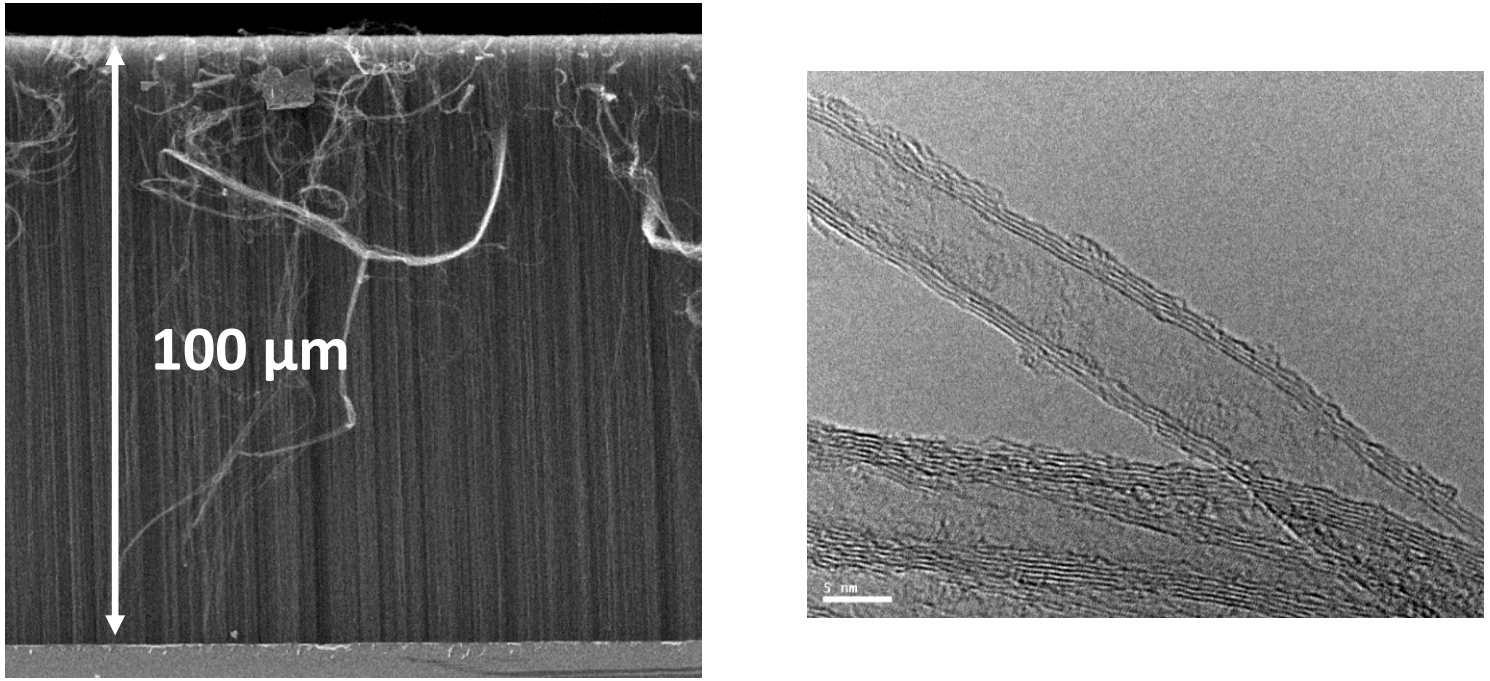


Figure 1: Production of CNT forests.



(a) (b)

Figure 2: (a) SEM image of CNT forest (b) HRTEM image of MWCNTs.

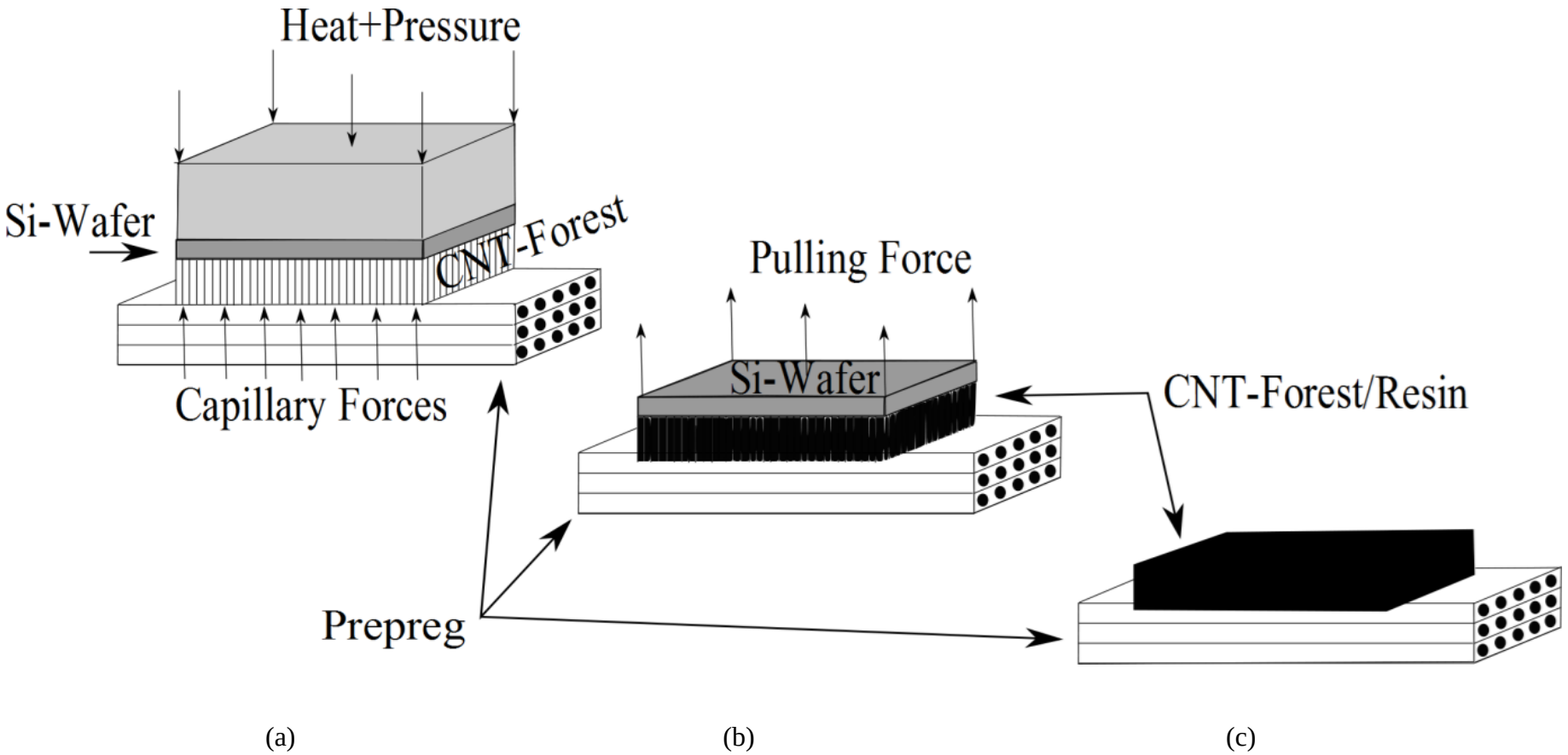


Figure 3: Transplanatation of CNT forest (a) heat and pressure applied to silicon substrate (b) removal of the substrate after the cool down period (c) transplanted CNT forest infused with resin through capillary action and partially inserted into the prepreg.

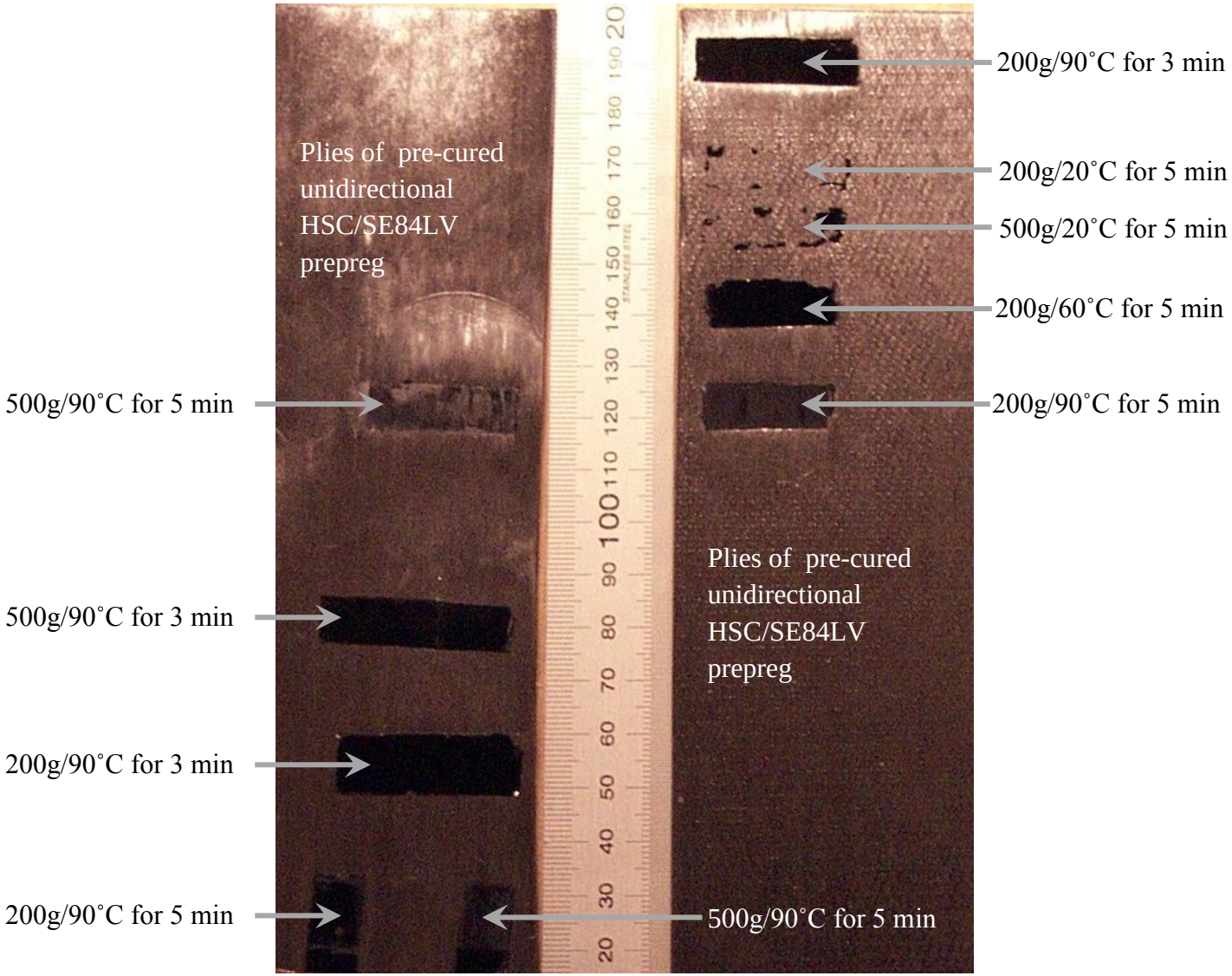
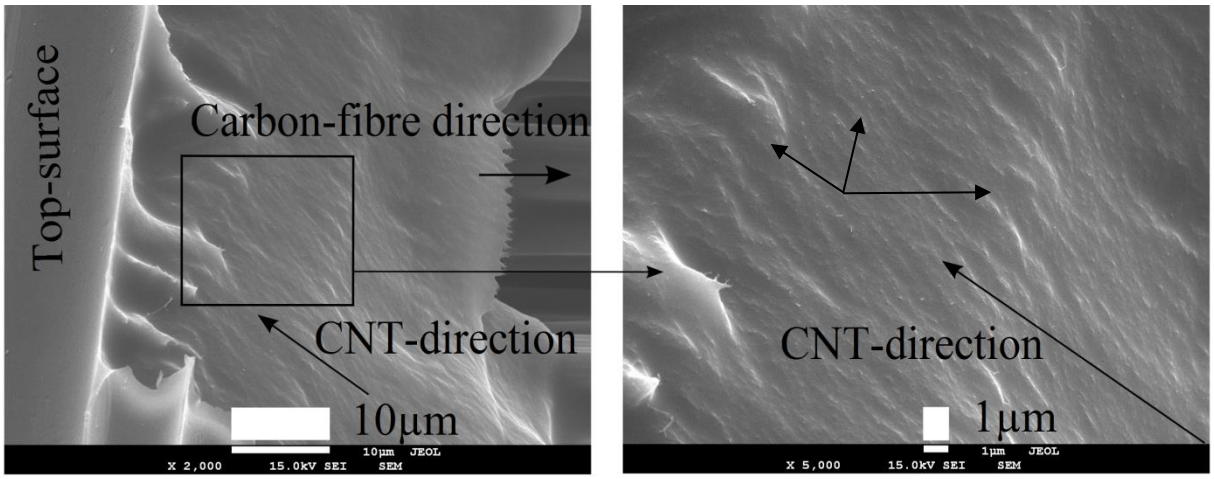
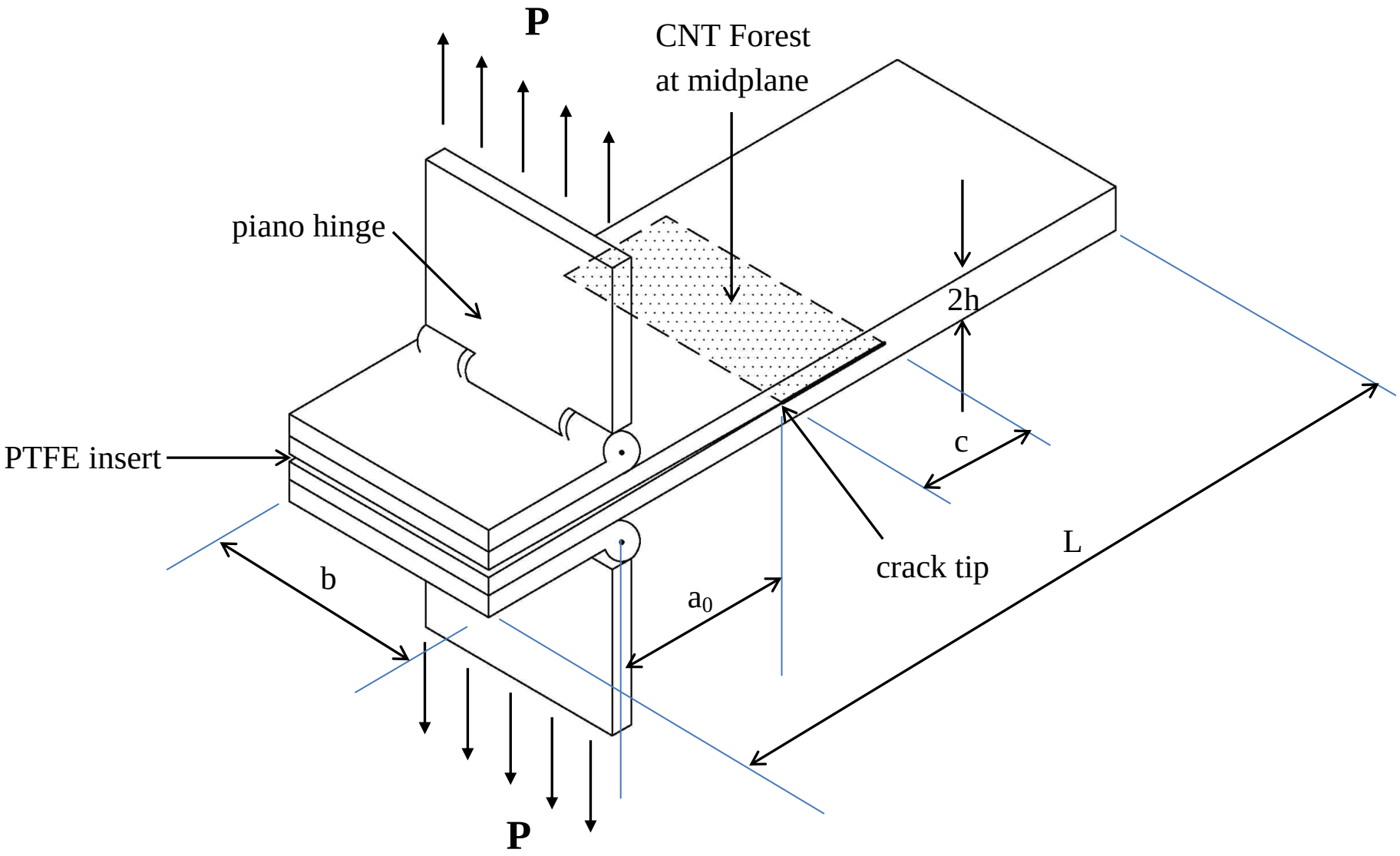


Figure 4: Transplantation tests using combinations of heat and pressure (T700/SE84LV).



(a) (b)

Figure 5: (a) CNT forest (b) detail of CNT forest showing complete wetting.


P
CNT Forest
at midplane
piano hinge
2h
PTFE insert
c
b
crack tip
L
a_0
P

(a)

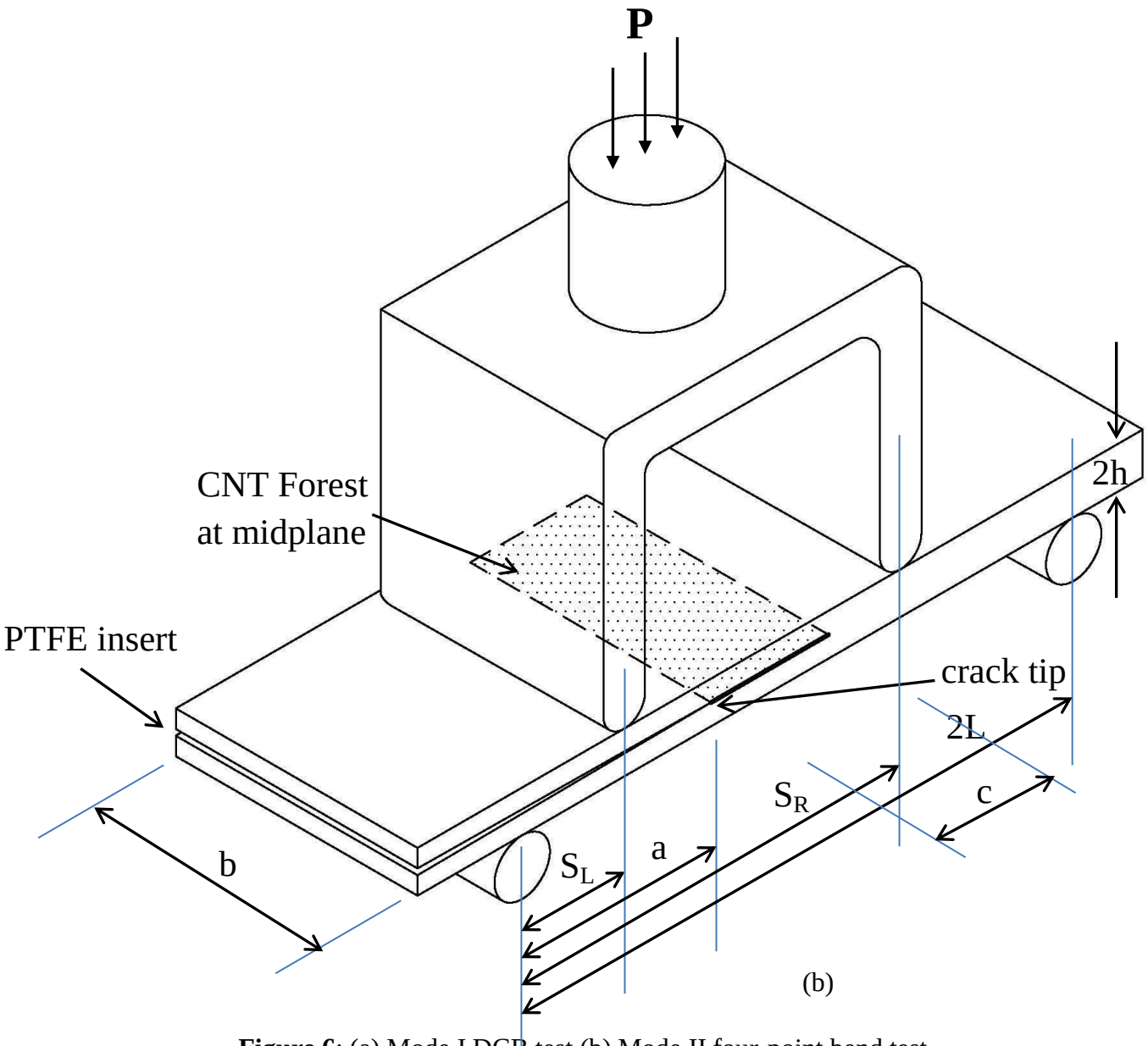


Figure 6: (a) Mode I DCB test (b) Mode II four-point bend test.

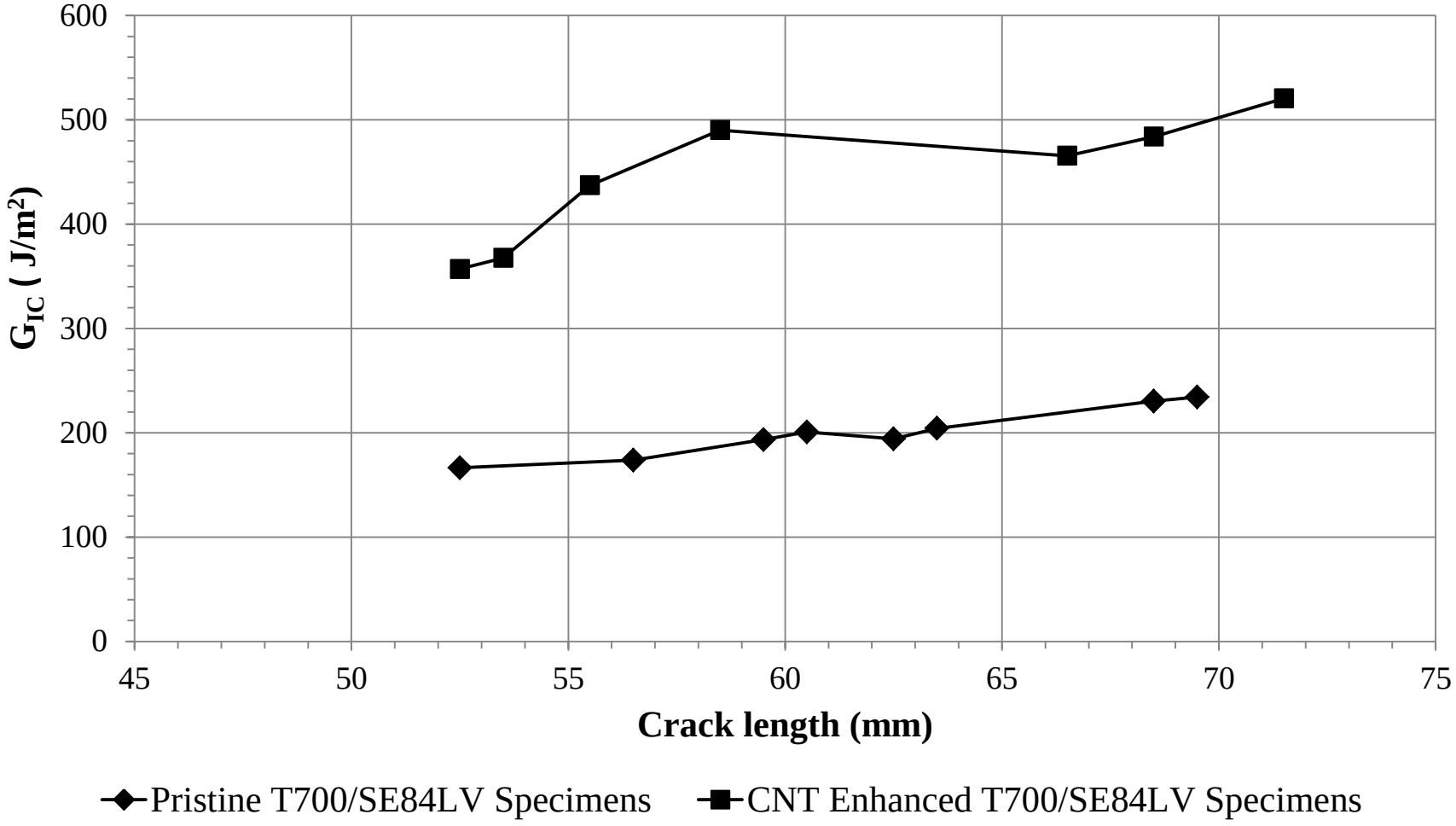


Figure 7: Representative R-curves from GURIT T700/SE84LV Mode I DCB tests.

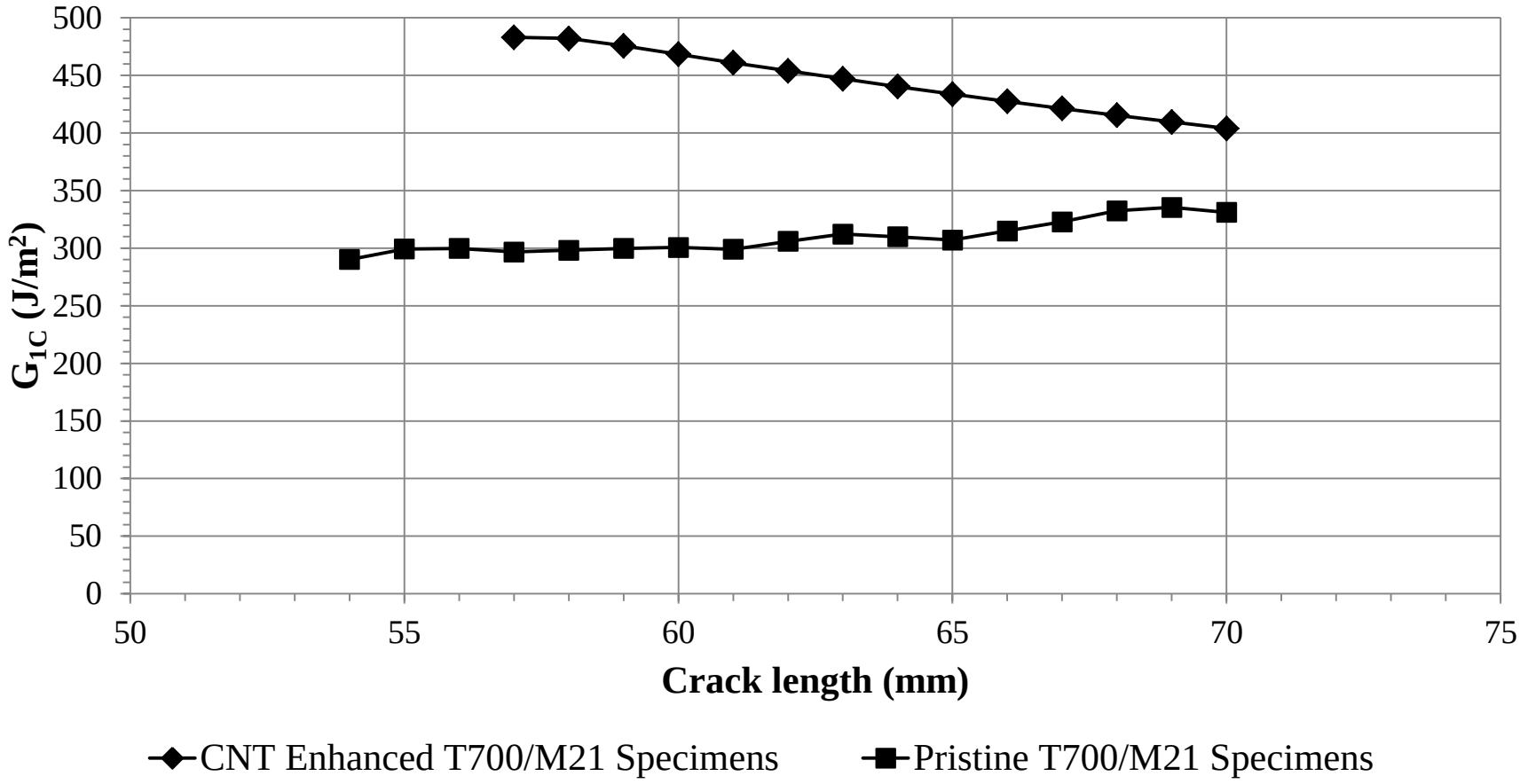


Figure 8: Representative R-curves from HEXCEL T700/M21 Mode I DCB tests.

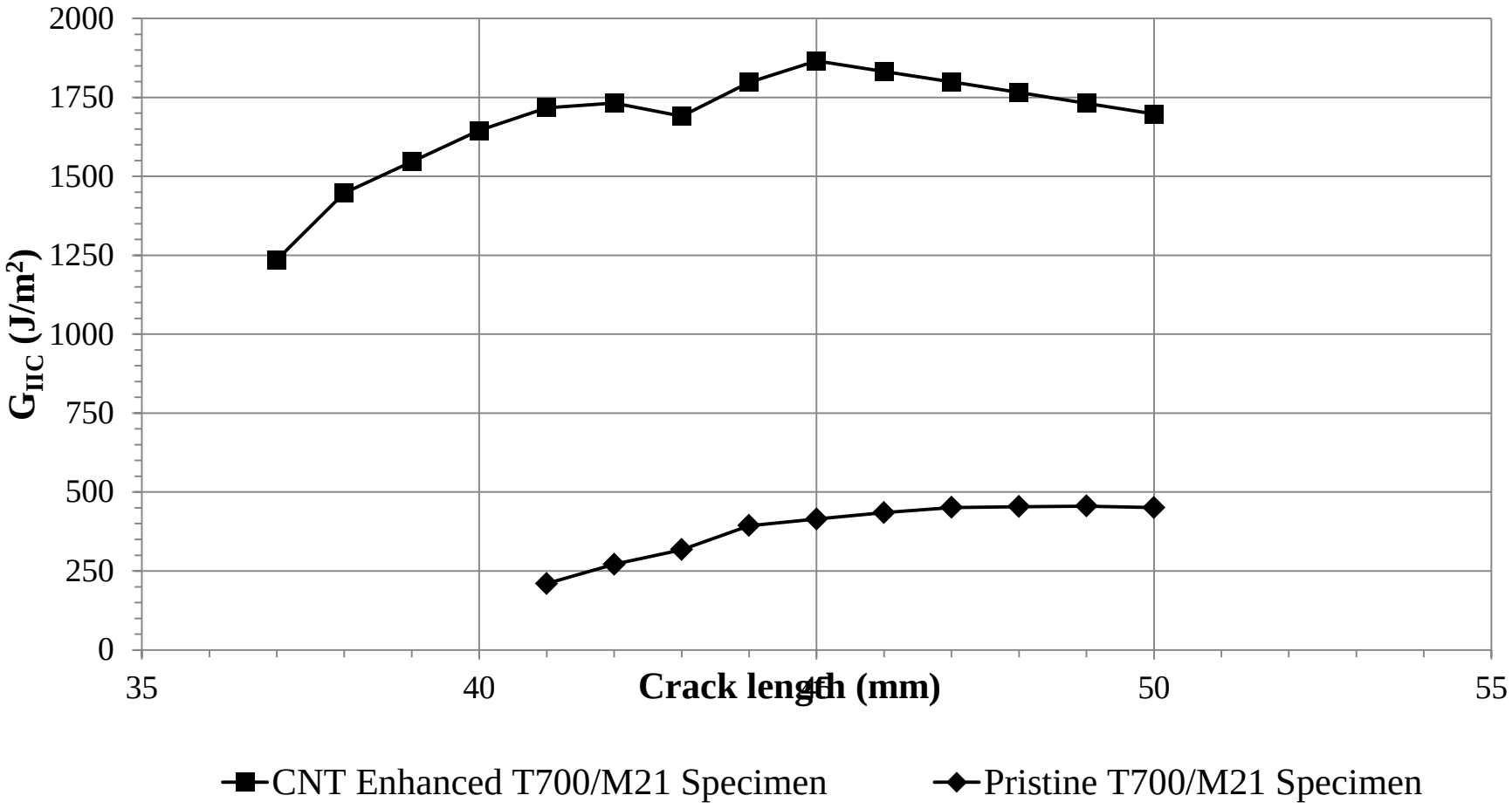
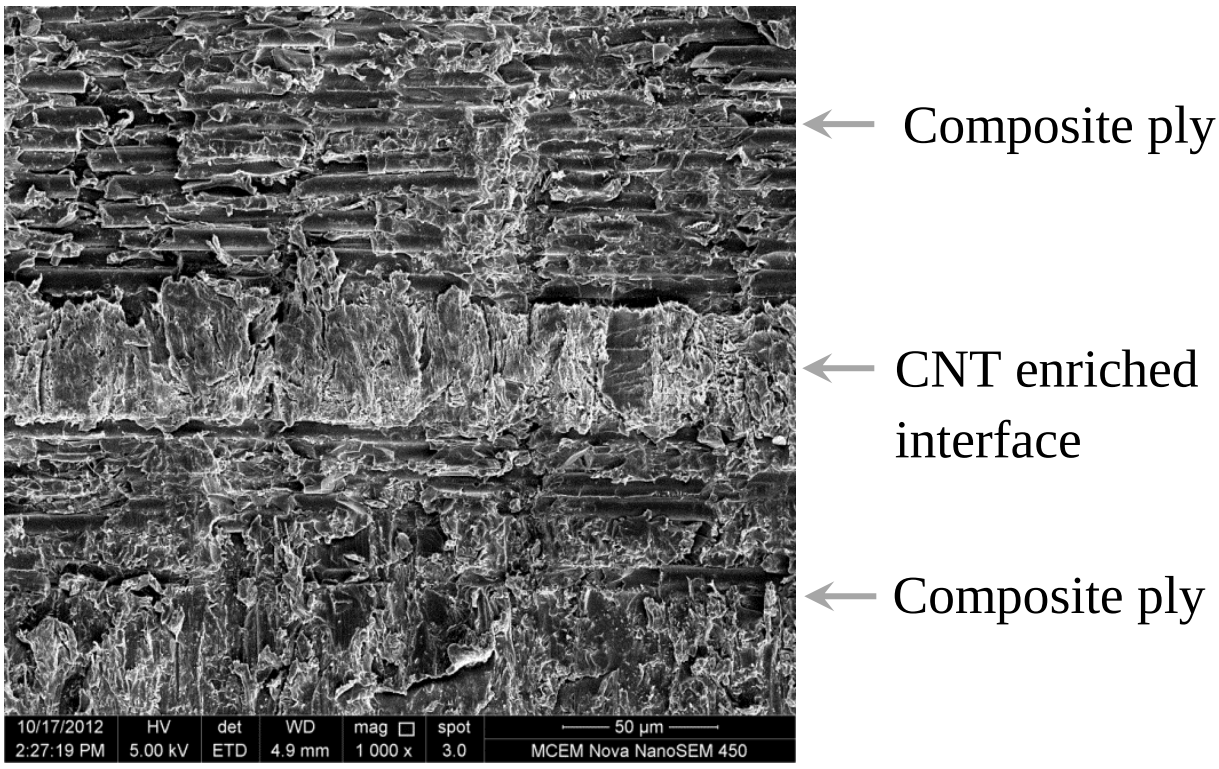
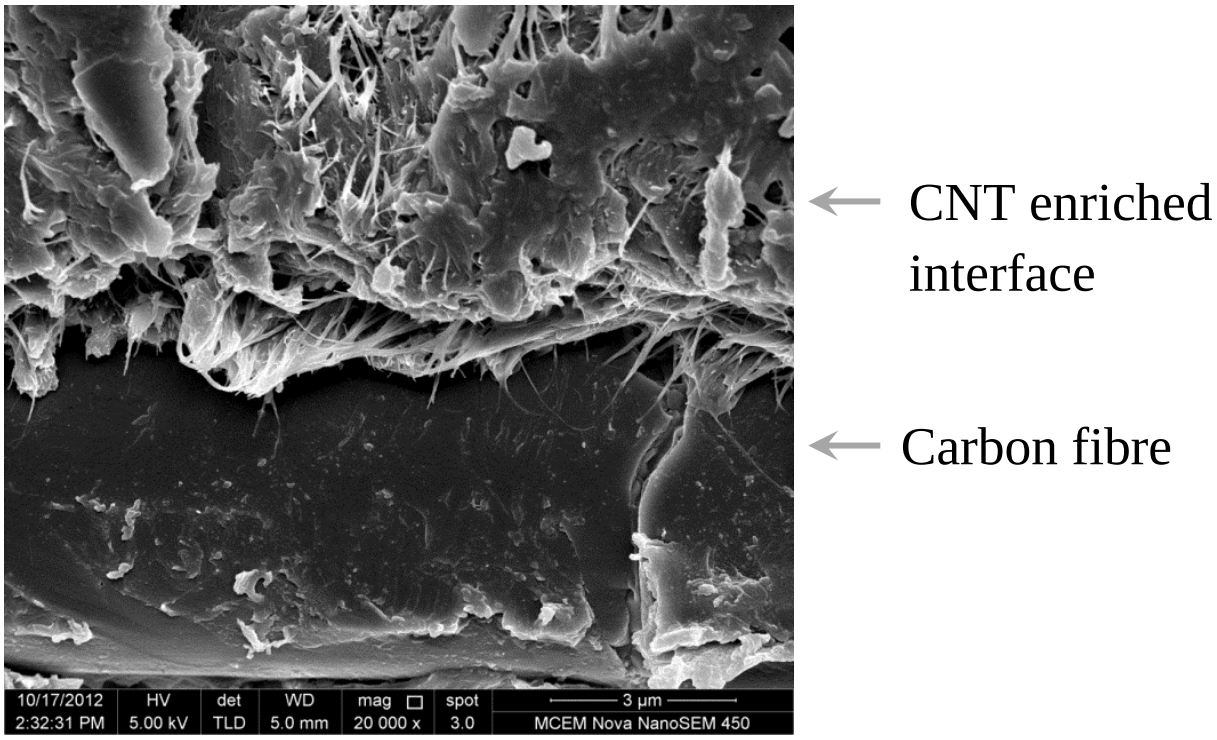


Figure 9: Representative R-curves from HEXCEL T700/M21 Mode II DCB tests.



(a)



(b)

Figure 10: (a) SEM image showing embedded CNT forest (b) CNT forest wrapped around carbon-fibre.

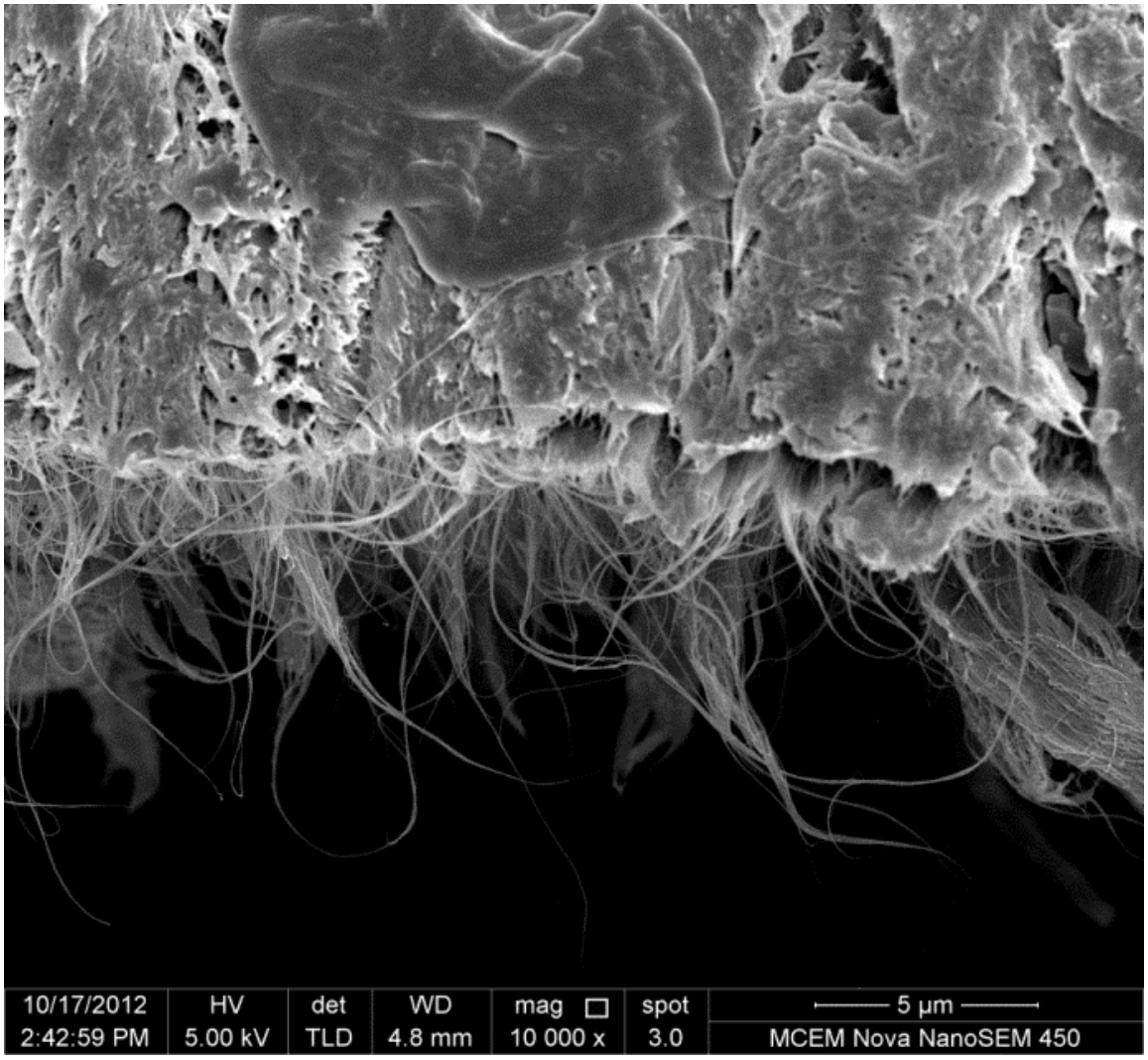


Figure 11: Fracture surface showing ‘sword-in-sheath’ failure mechanism of MWCNTs.

Table 1: Mode I and Mode II fracture toughness values (average ± one standard deviation)

Specimen material	**Fracture mode**	**Specimen type**	**Average fracture toughness (J/m^2)**	**Number of specimens**	**Average increase in fracture toughness**
T700/SE84LV	I	Pristine	210 ± 17.8	6	
		CNT forest	338 ± 96.2	3	61%
T700/M21	I	Pristine	331 ± 19.2	5	
		CNT forest	435 ± 12.0	2	31%
T700/M21	II	Pristine	443 ± 283	4	
		CNT forest	1155 ± 479	5	161%